Volume 108
Number 1
Spring 2022

Journal of the

WASHINGTON

ACADEMY OF SCIENCES

WASHINGTON ACADEMY OF SCIENCES
1898

ISSN 0043-0439

Issued Quarterly at Washington DC

Washington Academy of Sciences

Founded in 1898

Journal of the Washington Academy of Sciences (ISSN 0043-0439)

Published by the Washington Academy of Sciences
email: editor@washacadsci.org
website: www.washacadsci.org

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EDITOR'S COMMENTS

It is my honor to assume the role of the new editor of the Journal of the Washington Academy of Sciences. Let me start by expressing my appreciation to the academy members, authors and reviewers for your continued support to our journal. My commitment is to do my best to keep our journal strong and successful. Special thanks is due to Sethanne Howard, our outgoing editor, who served with distinction and dedication for the last 20 years. We can look forward to continued dissemination of articles and special issues that are informative, interesting and provocative. Last, but not least, let me thank the Board of Managers for their support, and Terry Longstreth for handling the printing and distribution of the journal.

This issue is my inaugural issue and it spans science both in time, from Aristotle to the current COVID-19 pandemic, and in subject matter, including articles on physics, biology, and ecology.

Please send your comments on papers, suggestions for articles, and ideas for what you would like to see in the Journal to me at this address: editor@washacadsci.org.

Kenneth Baclawski

Journal of the Washington Academy of Sciences

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THE SARS-CoV-2 PANDEMIC AND FEMALE ATTRITION RATES IN STEMM ACADEMICS

Judy Staveley

Abstract

According to a recent study conducted by the National Academies of Sciences, Engineering, and Medicine (2021), emerging evidence has shown that the SARS-CoV-2 pandemic is negatively impacting females in STEMM academics. STEMM is an abbreviation for science, technology, math, and medicine (STEMM) (National Academy of Sciences, Engineering, and Medicine, 2019). Leading up to the pandemic, the female attrition rates for females in STEMM academics were already high. SARS-CoV-2 led university campuses to close and transformed teaching methods. These changes in educational practices have brought on stressors and anxieties for women in STEMM education leading to high attrition rates. In this study, the researcher analyzes the problem and solutions to retaining females in STEMM academics and careers. In conclusion, mentoring programs have been shown to retain women in STEMM academics and careers.

Introduction and Background

THE PROBLEM OF HIGH ATTRITION RATES among female undergraduate and graduate students in STEMM academics is increasing because of the SARS-CoV-2 pandemic. Female undergraduate and graduate science students are continuing to experience several barriers and stressors such as anxiety mental health risks because of the SARS-CoV-2 pandemic (Bloodhart et al., 2020; Hinton et al., 2020; Hofstra et al., 2020, National Academies of Sciences, Engineering, and Medicine, 2021, Staveley, 2021). STEMM is an abbreviation for science, technology, math, and medicine (STEMM) (National Academy of Sciences, Engineering, and Medicine, 2019).

This paper seeks to address the problem of increasing STEMM attrition rates amongst female undergraduate and graduate students and advocate for creative teaching methodologies and mentoring programs to retain these students in STEMM academic programs. The most vulnerable students in this pandemic are economically disadvantaged female STEMM undergraduate and graduate students such as Latins, Blacks, and Native Americans (Meulemans, 2019, Lobos, 2021, Staveley, 2019, 2021).

Several reports have highlighted that SARS-CoV-2 has disrupted STEMM academics for undergraduate and graduate female students (Bernacki et al., 2020, Brown et al., 2020, Cromley & Kunze, 2021, National Academies of Sciences, Engineering, and Medicine, 2021, Meulemans, 2019, Lobos, 2021). The start of the 2020 SARS-CoV-2 pandemic changed how everyone conducted their personal, professional, and academic lives. These disruptions shifted the way STEMM students learned. The preliminary evidence gathered in this report indicates that SARS-CoV-2 has disrupted STEMM academic learning for female STEMM undergraduates, graduates, and underrepresented female students. These negative shifts have led to undesirable STEMM academic barriers, career progressions, increased challenges, and work conflicting responsibilities (Cromley & Kunze, 2021, National Academies of Sciences, Engineering, and Medicine, 2021).

According to the National Academies of Sciences, Engineering, and Medicine (2021), the investigations of the impact of SARS-CoV-2 on females in STEMM academics revealed that academic productivity disproportionately affected females compared to men. Additionally, the report also informed that the pandemic has intensified work-life boundaries which increased academic workload, decreased productivity, increased difficulty in interacting with colleagues, changes in teaching methodology, negative impact on scientific research, and less time to work. The SARS-CoV-2 pandemic has disrupted the undergraduate and graduate STEMM academic programs for females. These disruptions have been shown to weigh disproportionally on all-female STEMM academic students.

According to Staveley (2021), survey findings revealed that Biology, Biochemistry, and Engineering female undergraduate students reported similar disruptions to their academic programs owing to SARS-CoV-2 academic policies. Staveley's (2019, 2021) findings also stated that the undergraduate females in STEMM undergraduate academics felt more stress in science courses, experienced a lack of sense of belonging, and a lack of support because of the disruptions from SARS-CoV-2 disruptions. Undergraduate and graduate STEMM students continue to experience barriers in advanced STEMM degrees (Staveley, 2019, 2021).

According to Sci-ops (2021) reported survey findings, a large majority of research scientists reported that SARS-CoV-2 policies substantially impacted their research and disrupted scientific collaborations, lab work, and advancement in science academics for

undergraduates and graduate STEMM students. The most-reported positive impact that was reported in the Sci-ops research survey was increased opportunities for writing, reviewing new research topics (35%), reviewing prior data collected for new research (30%), and having access to more virtual seminars for these STEMM students (Sci-ops, 2021).

Support and Needs of Females in STEMM Academics

Research revealed that undergraduate and graduate females struggling in STEMM academics resulted from a lack of support. The research report findings in these studies signified that undergraduate and graduate female students in STEMM academic programs struggle with overall mental health, happiness, and emotional support (Bernacki et al., 2020, Brown et al., 2020, Cromley & Kunze, 2021, National Academies of Sciences, Engineering, and Medicine, 2021, Meulemans, 2019, Lobos, 2021, Staveley, 2019, 2021). Female academic students in STEMM undergraduate and graduate programs also reported that they experienced struggling with time management owed to family responsibilities, lack of access to resources, internships, laboratories, academic support, and other logistical problems that could help them with their academic success.

Students also reported positive outcomes of feeling motivated, encouraged, and confident when a science mentor supported them through their STEMM academics and STEMM careers. Students expressed that mentoring support is a solution to decrease high attrition rates in STEMM academics (Cidlinská, 2019, Cromley & Kunze, 2021, National Academies of Sciences, Engineering, and Medicine, 202, Staveley, 2019, 2021).

Goals and Recommendations

As the pandemic lingers, mentorship has shown to be an essential component to advancing STEMM education. Having a mentor is a powerful tool for female undergraduate and graduate STEMM students. STEMM female students have reported in research reports that having a role model or a mentor has had a positive outcome on their academic STEMM goals (Staveley, 2021). In addition, they conveyed that having a mentoring program, attending conferences, and having virtual meetings had a positive impact on their educational learning. Unfortunately, the SARS-CoV-2 pandemic has negative effects on STEMM academic programs and scientific research. The positive reports have shown that supporting undergraduate and graduate females in STEMM academics,

research, and careers will guide them on the path to success (Averson, 2020, Bernacki et al., 2020, Brown et al., 2020, Cromley & Kunze, 2021, National Academies of Sciences, Engineering, and Medicine, 2021, Meulemans, 2019, Lobos, 2021, Staveley, 2019, 2021). A one-on-one relationship mentoring session or group mentoring program can support undergraduate and graduate females to persist through their science courses. In addition, these programs can promote science learning education and resilience for academic success. Educational institutions should set goals and strategies to support struggling undergraduate and graduate female STEMM students. This support will help retain these students in academic programs and decrease high attrition rates (Staveley, 2021). To decrease high attrition rates in educational institutions, educational leadership needs to focus on enhancing collaboration with scientific societies, incorporating learning and motivating workshops, coordinating with mentors to support efforts for females in STEMM. Educational institutions should monitor the long-term negative impacts of the SARS-CoV-2 pandemic and how it affects undergraduate and graduate females in STEMM academic programs. These studies advocate for female students in STEMM academics.

Community Collaboration

Educational leaders ought to be working on ensuring the success of undergraduate and graduate females in STEMM academics. High attrition rates in females in STEMM academic programs are continuing to rise (National Academies of Sciences, Engineering, and Medicine, 2021, Lobos, 2021, Staveley, 2019, 2021). Scientific organizations and similar community science programs can proactively advocate for undergraduate and graduate female students by offering workshops and seminars that target change in academic institutions to help decrease high attrition rates (National Academies of Sciences, Engineering, and Medicine, 2021, Lobos, 2021, Staveley, 2019, 2021).

Scientific organizations can furthermore support these undergraduate and graduate STEMM female students by providing mentors that will motivate, act as role models, and help these STEMM female students to stay engaged in their academic goals. Setting up online virtual lectures, panel speakers, online study sessions, and offering other resources are some supportive strategies. A strong science community is essential for advocating for these undergraduate and graduate female science students. This pandemic is still a threat to our female undergraduate and graduate students in STEMM academics.

Underrepresented undergraduate and graduate females in STEMM academics, such as Latinas, Blacks, and Native American females are the ones who suffer the most impacts in academics (Mishra, 2020, Staveley, 2019, 2021).

Conclusion

In conclusion, recent research findings have shown long-term negative impacts that affect undergraduate and graduate females in STEMM academics since the start of the SARS-CoV-2 pandemic. These negative impacts will be long-term according to the National Academies of Sciences, Engineering, and Medicine, 2021. SARS-CoV-2 pandemic is a public health emergency and has posed many challenges for our female STEMM academic programs. With the assistance of scientific societies and STEMM outreach support systems, these students may overcome barriers they may be experiencing.

Research findings have revealed that positive outcomes through mentoring programs and support can positively impact and decrease high attrition rates in STEMM academics. Mentoring programs have shown to be a successful tool in supporting females in scientific disciplines and research. In addition, the findings and recommendations presented in this paper should be implemented in the scientific community and within educational institutions to further support females in STEMM. The SARS-CoV-2 virus is becoming endemic and is likely here to stay (Phillips, 2021). Recommended pathways that educators should consider are to be creative with their educational resources for female students in STEMM academics, provide educational outreach programs through virtual workshops, and be empathetic with students' social and emotional challenges that they may be enduring. Our female STEMM students have been through so much in these last two years of the pandemic, and educators need to support our students to the proper mental health professionals that can guide them in the right direction.

As educational institutions start operating normally again, education and administrators will need to face the issues brought on by SARS-CoV-2. Educational leadership requires preparation and the need to respond to the new endemic by centering equity and social justice for these females in STEMM academics. In addition, educational leaders will require to train teachers and staff how to work together and collaboratively work towards a common goal. Preparation is key to success for future disruptions.

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Aristotle's Concept of Heredity

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Abstract

About a quarter of Aristotle's surviving writing is about biology, and some of that focusses on reproduction and heredity, particularly in his *Generation of Animals*, in which he describes a model of reproduction and heredity that is arguably congruent with modern understanding. To demonstrate that congruency, 12 statements from *Generation of Animals* are interpreted for their agreement with modern models of reproduction and heredity, followed by brief discussion of previous comments on this issue. It is concluded that, despite not assuming modern theories of genes-based heredity, Aristotle described a model that is mostly congruent with those theories.

Introduction: Aristotle as Biologist

TRADITIONALLY, ARISTOTLE IS referred to as a philosopher, but over a quarter of his surviving work is about biology, a fact that is often unexpected by scientists (Gotthelf and Lennox 1987).[1] One aspect of that work on biology is about reproduction and heredity, described most fully in the Generation of Animals (GA), although Aristotle also makes comments about reproduction in other works, primarily *Parts of Animals and Metaphysics*. Thus, the GA is relevant to both philosophers and scientists because it is concerned with sexual reproduction, and also because Aristotle may be seen to have applied a fledgling Scientific Method in this work (Gotthelf 2012, p. 58).[2]

Although the GA encompasses a very great number of issues, examples, and comments about the reproductive and heredity processes, this paper is focused upon a specific aspect of the GA—that of how the inheritance of characteristics occurs during reproduction, and how closely Aristotle's work parallels a modern theory of DNA-based heredity. To elucidate the nature of Aristotle's concept of reproduction and heredity, selected excerpts from the GA will be examined for their agreement with modern understanding of reproduction and heredity. Following this, the relevant literature will be briefly reported, evidencing the wide range of opinions on this issue. After these two steps, a conclusion will be drawn regarding the verisimilitude of Aristotle's concepts of reproduction and heredity.

Aristotle's model of reproduction and heredity *vis-à-vis* modern understanding

The field of reproduction and heredity is extremely large and complex and, if the comparison between Aristotle's models and the modern understanding of these matters were undertaken by listing the principles of modern genetics and then examining the GA to see if Aristotle mentioned all of these, it would be largely futile (and possibly unfair).[3] Instead, if Aristotle's major claims about reproduction and heredity were tested against modern models of those processes, then the validity of his statements might be examined more fruitfully. Thus, what may be useful is to examine what Aristotle said about the *general principles* of reproduction and heredity and determine the authenticity of his statements *vis-à-vis* modern understanding of these processes, disregarding the (necessary) incompleteness of Aristotle's model.[4]

To make this evaluation, a selection of 12 of the most relevant comments made by Aristotle that represent his model of reproduction and inheritance are discussed here.

1. "*all of those animals which are produced by a union of animals of the same kind generate also after their kind*" (GA I, 715b 2-3).[5]

As well as being one of the first places where Aristotle suggests that there is some process by which parental features are transmitted to their offspring, this claim is congruent with the traditional definition of a 'species' in modern biology, i.e.., that its members can only reproduce with each other, called "reproductive isolation" (Snustad and Simmons, 2000, p.796). This restriction occurs at the pre-conception level (where the female ovum rejects sperm from different species) or post-conception (where the viability of the hybrid is impaired) (Snustad and Simmons, 2000, p.796).

Aristotle is generally correct here. Although various animals can reproduce across species (e.g., the 'liger', which is the result of a tiger and a lion mating; several hybrids within the equine family; and the sheep-goat hybrid), most of these types of hybrids are infertile, and occur only when the two parents are close relatives (Gabryś et al., 2021).[6] Similarly, although different species of hominids did interbreed in the distant past, including Neanderthals and the ancestors of modern humans, these instances of interbreeding may have occurred relatively infrequently (Rogers, Harris, and Achenbach, 2020).[7] Thus, Aristotle is probably

correct on this point, and certainly for the period of at least the last 50,000 years. (Enard and Petrov, 2018, p. 360).

2. "*male and female principles*", are the "*origins of generation, the former as containing the efficient cause of generation, the latter the material of it*" (GA I, 716a 5-7).

Aristotle posits that, in sexual reproduction, the male and female are both necessary, which is a correct statement under modern explanations of sexual reproduction. His allocation of the male as having "the efficient cause," and the female "the material" is not correct genetically, because both male and female contribute almost equally to the formation of the embryo via their own sets of genes. However, it is correct that, following conception, the female contributes the cytoplasm (including the mitochondrial DNA) and the 'material' by which the foetus develops, the male having no further part in that process. In that respect, Aristotle's allocation of resources to grow the foetus is correct.

3. "*semen: for it is out of this that those creatures are formed which are produced in the ordinary course of nature*" (GA I, 716 8-9).

Aristotle's comment may be interpreted as analogous with modern understanding in that he allocates causal responsibility for the reproductive process to the 'semen' rather than to some spiritual agency. He adds that semen "is of such a nature" that "things that are naturally formed...come into being," which is analogous to the function of chromosomes, genes, and DNA (GA I, 724 16-20). He continues this theme to state that the semen "comes into being from the male and female," and that this semen "is secreted from the two sexes, the secretion taking place *in* them and *from* them (his italics), that they are the first principles of generation." (GA I, 716 11-13).[8] These statements further reiterate his contention that the process of reproduction relies on the semen from both sexes. This is congruent with the role that modern genetics gives to the sperm and ovum, each of which contain the chromosomes of the respective parent (Snustad and Simmons, 2000, p. 117).

4. "*it is thought that all animals are generated out of semen, and that the semen comes from the parents*" (GA I, 721 6-7).

Although this is very similar to the preceding statement, at this point Aristotle is mainly concerned with refuting earlier theories of embryogenesis, which claimed that preformed organs were already present in the parents' seed. He is correct in terms of modern understanding

because there are no tiny homunculi present within the male semen or the female ovum. He goes on in this section of the GA to discuss the nature of semen as "that which has in it the principles of generation" and "from which is finally formed each of the parts of the body," again describing the role attributed to genes in modern models of heredity (GA I, 724 13; 725 12-13). It is important to note that Aristotle requires both parents (in sexual reproduction) to contribute to the semen (as he describes it here), and that he allocates the causal responsibility for reproduction of "each of the parts of the body" (referring to the offspring's body) to this combination of mother's and father's own "semen" (GA I, 725 13). His claim that the union of mother's and father's "semen" contains "the principles of generation" indicates that he is describing a model of reproduction that is congruent with the principle of modern understanding that mother's and father's genes are the sole source of the initial genetic makeup of the offspring (Snustad and Simmons, 2000, p.35).

5. *"Children... resemble their parents more than their remote ancestors, and resemble those ancestors more than any chance individual" … "the resemblances recur at an interval of many generations" … "the woman in Elis who had intercourse with a Negro; her daughter was not negroid but the son of that daughter was."* (GA IV, 767b 1-31; 722 7-11)

Several points regarding inheritance are encapsulated within these statements. The first statement is correct in terms of modern genetics because offspring share a greater proportion of their parents' genome than they do of their grandparents' (for example) simply because they have two sources of chromosomes from their parents (i.e., their mother and father), but four from their grandparents (four grandparents); in the process of cross-over, only one complete set of (offspring) chromosomes is derived from these sources (Snustad and Simmons, 2000, p.36). This division of the sources of heredity increases with further generations, until the proportion of a many-generation ancestor's genes that are influential within a specific child is relatively small. However, it is not so small as to be absent altogether, which is Aristotle's second point in the first phrase quoted above ("resemble their ancestors more than any chance individual"), compared to a child from a different set of ancestors.

When Aristotle argues that "the resemblances" may not be present within the first generation but may appear in a later generation, he is also correct, as confirmed by Mendel in 1865 (Klug et al., 2017, p. 48). Mendel notes that, when he crossed tall pea plants with dwarf pea plants, the next generation did not exhibit the same degree of tallness/dwarfism, but the

following generation did. This is due to the phenomenon of 'dominant' and 'recessive' alleles (a single gene). Alleles affect the traits of offspring by producing particular proteins that influence the way the foetus develops (proteins are strings of amino acids). Some alleles may be carried from one generation to the next but not show in the offspring because parents have a combination of dominant and recessive alleles, and the particular allele may be dominated by another. However, in a further generation, both parents may have a combination of the same alleles, thus making it dominant and producing the trait in their offspring.

6. "*the female contributes the material for generation, and this is in the substance of the menstrual discharges*." (GA I, 727 31-33)

This comment contains an element of physiology and may be interpreted in two ways. First, if Aristotle is referring to the process of embryonic development, the embryo develops via nutrition received from the mother while within the womb, so the first part of the comment is correct. However, if he is arguing that that nutrition comes directly from the mother's menstrual processes, he is incorrect, because menstruation ceases at conception. Instead, nutrition for the embryo's development is provided via blood from the mother, reaching the foetus via the mother's umbilical cord, which connects the foetus to the mother's placenta, situated within the womb (Hall, 2016). If the common factor of the mother's blood supply was accepted (i.e., in the menses and in placental blood flow), then Aristotle could be interpreted as accurate on this point.

7. "*the female is passive...and the male is active, and the principle of movement comes from him*." (GA I, 729 13-14)

There is no evidence for this claim in modern genetics.[9] Both mother and father contribute with equal probability to the formation of those traits which are exhibited in the offspring, via the process of fertilisation. Aristotle bases his argument that the male is the "active" agent on the premise that it is "the character of the female" that she "has by nature a smaller portion of heat" (GA I, 726 34-35). Taken on that basis, although his argument is reasonable under his model of male vs female physiology and innate heat, his premise regarding that difference in heat between the sexes is not correct.

8. "*the female does not produce young if the (menstrual) discharge is absent altogether, nor often when...the efflux still continues; but she does so after purgation*." (GA I, 727 11-13)

Although this statement is part genetics and part physiology, Aristotle is correct here. The menstrual discharge is indicative of ovulation having occurred but no longer being possible within that menstrual cycle. Without ovulation, there is no ovum prepared for fertilization, and the male sperm cannot enter it to form a zygote and thence an embryo (Hall 2016, p. 1012). The reference to "after purgation" is also correct, since ovulation occurs approximately 10 days after the end of menstruation (i.e., "purgation") (Hall, 2016, p. 1013).

9. "*More males are born if copulation takes place when the north than when the south winds are blowing*" (GA IV, 766 34-35)

This is another of Aristotle's statements that contains a portion of physiology as well as genetics. His explanations for the cause of the embryo's sex are clearly wrong in terms of modern genetics, but are based upon his notion of "innate heat" (which is influenced by the direction of the wind—a phenomenon that would only occur in the northern hemisphere, if at all). Instead, the sex of the offspring is determined by the contribution of a Y chromosome from the father's genome to the embryo, which "directs the primordial gonads to develop into testes" and the male physiological profile (Snustad and Simmons, 2000, p. 129).

10. "*some of the movements exist actually, others potentially*". (GA IV, 768 12-13)

Here Aristotle is arguing that some characteristics dominate over others, or what would be termed as 'dominant' versus 'recessive' genes in modern explanations of heredity. He does so by reference to those characteristics that come from the "father and the general type, as man and animal" as being dominant ("actual"), and those from "the female and remoter ancestors" as being recessive ("potential"). He adds that, should "the movement of the male parent relapse," then the resemblance of the offspring "changes by a very slight difference into that of his father, and in the next instance to that of his grandfather;" the same happens if the movement of the female relapses, so that the offspring resembles her mother and then grandmother; this also continues "with the more remote ancestors" (GA IV, 768a 15-20). Although not written in the terminology accepted today, Aristotle's model does include the correct explanation—some characteristics dominate over others.

11. "*the semen, though one, is as it were a seed-aggregate of many elements...the offspring resembles the parent from which it has derived most.*" (GA IV, 769a 29, 35).

This statement may be interpreted as congruent with the notion of genes and chromosomes. Aristotle acknowledges that (a) the semen is complex and made of many "elements," and (b) the offspring is a combination of those elements which it derives from each parent. This is probably as close as Aristotle comes to a modern theory of genes and chromosomes because he argues that the semen is a "seed," from which the embryo grows, and that it is composed of many elements, verified by the model of the human genome as composed of 23 pairs of chromosomes, thus 46 in all (Tijo and Levan, 1956; Levy et al. 2007). Each of these chromosomes consists of a number of genes, from hundreds to thousands. Overall, each human has about 20,000 to 23,000 genes, and these code for the formation of specific proteins, each of which functions to influence the developing embryo in particular ways, such as sex, and colour of skin; these are called 'traits' or gene-derived characteristics (Klug et al, 2017, p. 48). Although there are sometimes flaws in genes, which can produce malformed proteins which then contribute to the likelihood of specific abnormalities, environmental factors can also influence the way the gene functions to produce proteins, such as external radiation, infection while the foetus is in utero, or lack of adequate nutrition (Klug et al. 2017, pp. 273-275).

By perceiving that the semen must contain a wide range of 'elements', and that the offspring will resemble the parent from whose chromosomes they take 'most', Aristotle was closer to a modern theory of genetic-based hereditary than anyone prior to the mid-twentieth century. Based purely upon his observations and his reflections, this statement reflects a major step in understanding how heredity works.

12. "*even in a single act of intercourse the semen discharged is more than enough for one embryo, and this being divided causes more than one child to be born, the one which is later than the other.*" (GA IV, 773b 11-12).

Aristotle is correct in his estimation of the excess of semen in a male ejaculation (500-600 million sperm) and that this would be sufficient to fertilise very many ova indeed. However, he is incorrect in his account of how the second pregnancy forms—it is by the release of a second egg by the female or the splitting of an embryo, rather than simply the large amount of male ejaculate.[10]

The longevity of Aristotle's model of inheritance

It is worth noting that Aristotle's writings on reproduction and heredity persisted until 1875, when Hertwig (1892) showed (via microscopy) that fertilisation was accomplished when the sperm and egg fused. Of itself, this finding demonstrates that Aristotle's account of inheritance was accepted by the scientific community until technology provided an alternative, thus arguing for its logic and adherence to observations made by many centuries of medically- and biologically-oriented investigators.

The 12 statements from Aristotle discussed above might be used as a basis for considering Aristotle as describing a genes-based process of reproduction and heredity, and several authors have argued that case, although not without opposition. The major proponents of this argument are discussed below, in order to help place Aristotle's work on reproduction and heredity in context *vis-à-vis* modern understanding of these processes.

'Aristotle as Geneticist': summary of the previous literature

One of the earliest modern arguments regarding the 'Aristotle as geneticist' claim is made by Hans Driesch (1913), regarding *entelechy*; the major modern arguments regarding the 'Aristotle as geneticist' claim is made by Muller (1996, p. 23), who maintains that *entelecheia* (or its synonym *energia*) is "the efficient and final cause of a living body", so that "Development is governed by a principle which bears the end in itself and shapes structureless matter, striving for a species-specific form". These notes assume a genetic model of inheritance is present in GA, but do not state it as baldly as in perhaps the most influential comment about Aristotle's genetics from a major biologist, given by Ernst Mayr (1982, p. 89): "Aristotle's *eidos* is a teleonomic principle which performed in Aristotle's thinking precisely what the genetic program of the modern biologist performs." Even more specific is the comment by Delbruck (1971, p. 54-55): "It is my contention that Aristotle's principle of the "unmoved mover" perfectly describes DNA: it acts, creates form and development, and is not changed in the process." Zirkle (1951, p. 42) follows suit, noting that Aristotle's statement that "semen is a mixture of a larger number of ingredients, for the offspring take after that parent from which it derives most" is close to the understanding of genetic inheritance accepted in the twentieth century. Bartsocas (1984, p. 38) goes so far as to call Aristotle "the father of Genetics".

There is little room for doubt in these statements. Even if Aristotle did not use the current biological terms, these authors contend that he was describing a genetic model of inheritance. These opinions are not isolated. For example, although his article is mostly focused on ways in which “Aristotle's thoughts may yet play a remarkable role in contemporary scientific discussion”, Kullman (1991, p. 137) makes a case for Aristotle as geneticist, even arguing that he took this role in ways that were superior to Darwin because Aristotle argues that (in Kullmann’s words) “the purposeful structure of a living being depends on the programme pre-existing in the blood of the parents.”[11] Preus (1970, p. 6) sees Aristotle’s *eidos* as “a kind of "organizer" of the reproductive process, which may be somewhat akin to the actions of DNA itself. Consistent with that view, when discussing Aristotle’s explanation for “monstrosities,” Soardi (2017) notes that these occur when the female menstrual fluid fails to be adequately concocted by the male semen, and represent “failures of the purposive effort” (Aristotle, Physics, II, 199b 4). Such a monstrosity is visible when the offspring “do not replicate in the same way the form of their parents, making it impossible to establish a causal relation between parents and offspring,” akin to the deletion, duplication, inversion, or variation in arrangement of chromosomes that lead to genetic-based disorders (Soardi, 2017, p. 152; Klug, 2017, pp. 125-127). All of these comments and opinions focus attention towards Aristotle as a geneticist (even if in waiting for the technology of 2300 years later for confirmation of his model of inheritance).

David Henry draws our attention to one of Aristotle’s most famous statements in terms of inheritance: “for man produces man” (Aristotle, Metaphysics VII, 1033b 32). This is important because it clearly assumes that there is some aspect of the male semen and female menstrual fluid (that form the human embryo) that is unique to mankind (as distinct from horses, foxes, sheep, etc.). This assumption relies on a genetic-like model for its validity, and is extended in the rest of Aristotle’s sentence after he makes this point in the Parts of Animals (I, 640a 25-26): “For man is generated from man: and thus it is because the parent is such and such that the generation of the child is thus and so.” Aristotle is clearly pointing out a causal association here when he argues that the reason why the child is “thus and so” is because the parent is “such and such.” Although not unique to him, Aristotle clarifies the similarity in parents’ and offspring’s’ traits and characteristics (at least those that are not adventitious) as being due to the “creative seed endowed with certain powers” (i.e., the parents’ semen and menstrual fluid) (PA, I, 640a 23-24). At this point in the Parts

of Animals, Aristotle is focused upon refuting Empedocles' argument "that many of the characters presented by animals were merely the results of incidental occurrences during their development" (PA, I, 640a 20-22). Instead of this 'random effect' model of the superiority of the effect of environmental factors upon an individual's characteristics, Aristotle clearly placed the burden of those characteristics upon the individual's inheritance from their parents' "creative seed."

Henry further notes that, in the Metaphysics, "when Aristotle distinguishes between the nature that generates and the nature generated by it, he seems to be drawing roughly the same distinction modern biology makes between the genotype and the phenotype."[12] Aristotle makes this distinction also in the GA, when he claims that "For the material by which this latter (the product of nature—"the mature animal": see 740b 30) grows is the same as that from which it is constituted at first" (GA II, 740b 34-35). Aristotle's description of nature as "end" (the fully-developed mature adult form) and nature as "mover" (the productive agent within the developing embryo) leads Henry into a detailed discussion of the relative power of the male semen versus the female menstrual fluid, and he resolves this by arguing that both these genotyping sources have a role to play in determining the phenotype of the offspring (Henry, 2006, p. 427).

Essentially, Henry argues that "an organism's form is transmitted to its offspring by means of 'movements' which are said to be present in its male seed" (Henry, 2006, p. 442). Aristotle's words are clear on this point: first, he contends that "the offspring is produced indeed of a certain quality, but also as a certain 'this'", by which it is reasonable to infer that Aristotle is referring to the specific 'individual' characteristics (phenotype) that each person possesses and which, although resembling their parents, are also unique (GA IV, 767b 35-36). Henry concludes that "These movements are derived from the various 'potentials' of its genetic nature, each of which is the productive source of a different part of the animal's phenotypic nature" (Henry, 2006, p. 442).[13]

However, the field is not unanimous in accepting a genetic model for Aristotle's theory of inheritance. Apart from Grene's relatively short discussion of Aristotle's genetics (mentioned above and primarily aimed to refute Kullman), Vinci and Robert (2005, p. 202) challenge the claims put by Mayr, Henry, and others as being overly simplistic and mechanistic, and attributing to DNA a much more controlling role by "posit(ing) a decidedly un-Aristotelian genetic vitalism". Vinci and Robert (2005, p. 204) argue that DNA "is a strikingly inert molecule that must be activated

and triaged in order to function at all", and "is delimited by the cellular environment in which it is embedded." As such, DNA should not be considered as "an instruction manual," because "the 'instructions' are not 'just there'" in the DNA, but "need to be 'activated' at a given time in a given place by the complex environmental network in which it is embedded" (Vinci and Robert, 2005, p. 204). Instead, Vinci and Robert (2005, p. 219) maintain, DNA is "a jumble of nucleotides upon which order is imposed within the developing organism". Thus, they draw the analogy that, rather than being an instruction manual ready to impose a particular order upon zygote development, DNA is (in the words of Griffiths and Neuman-Held, 1999, p. 689), "a sequence of letters without spaces or punctuation marks", which is acted upon by the "state of the developmental system" to produce words, adding punctuation marks and editing notes.

Vinci and Robert raise an interesting point regarding the assumed agency of DNA, but it is only of tangential relevance to the question of whether Aristotle veers (even if unknowingly) towards a genetic model of inheritance. Although Aristotle does give the male semen an 'acting' role upon the female menstrual fluid, he simply does not (and technologically cannot) know enough about the detailed nature of DNA to engage with the points made by Vinci and Robert, regardless of their validity.

Instead, the issue under debate is whether Aristotle's model of inheritance *can be interpreted as congruent* with modern genetics. When Aristotle invests an agency into the male semen in its actions upon the female menstrual fluid, Vinci and Robert caution the reader against interpreting that to be an over-simplification of modern genetics. We might reply that, 'of course it is such an over-simplification', but it would be just as valid to argue that Aristotle's model of inheritance is invalid because he does not describe the male sperm swimming to the female ovum and then breaking through its membrane to merge the two sets of DNA. Aristotle (and anyone prior to the development of microscopy) could not know that this is what occurs at conception because there was not the technology to know it. That does not necessarily imply that Aristotle was not thinking along similar lines as has been proven in the modern scientifically-explored model of genetic inheritance, only that he was limited by his time and its technology.

On a related note, one of the most influential ideas in modern biology is 'epigenetics', first coined by Waddington (1956) as being "derived from the Greek word *epigenesis*, which Aristotle used for the

theory that development is brought about through a series of causal interactions between the various parts".[14] Waddington sees epigenetics as "'above genetics', or 'above the genes'" and is credited with initiating "a new and flourishing line of biological research under the 'Evo-Devo' label.[15] While no argument is made here that Aristotle was responsible for the modern concept of epigenetics, Waddington argues that the Parts of Animals has contributed to the development of that concept by Aristotle's description of semen as "a creative seed endowed with certain powers," and that this seed "is the origin and fabricator of its offspring" (Parts of Animals I, 645b 23-24). As far as Waddington's hypothesis is supported by Aristotle, it also argues for Aristotle's thinking to be congruent with modern genetics.

Summary of opinions regarding Aristotle's genetics

Of the 12 commentaries on the hypothesis of 'Aristotle-as-geneticist' discussed above, five were written by philosophers (Grene, Kullman, Preus, Henry, Vinci & Robert), one by a mathematician (Socardi), one by a medical practitioner (Bartsocas), one by a physicist (Delbruck), one by a botanist (Zirkle) and four by biologists (Dreisch, Muller, Mayr, LeRoi). The only paper to seriously challenge the 'Aristotle as geneticist' hypothesis was by two philosophers (Vinci, Roberts), and it could be argued that their thesis is based upon an accurate but essentially unfair assumption that somehow Aristotle should have understood how DNA functions.

Conclusion: Does Aristotle describe a 'genes-based' model of reproduction and heredity in the GA?

He does not, because he cannot. That is, he cannot discover the DNA double-helix that Franklin, Watson and Crick (1953) reported because he does not possess the X-ray crystallography facility that was needed to make that discovery. Neither does he discover the patterns of Mendel's generations of pea plants, but he could have done so, there being no sophisticated laboratory equipment needed. In this sense, the suggestion that Aristotle is a geneticist according to modern detailed expectations of heredity is patently false.[16] It may be argued that that is a function of the limitations placed upon him by the relative lack of technology necessary to describe chromosomes, genes, DNA, etc., but there were no restrictions upon his ability to plant peas and observe their patterns of heredity. So, the argument regarding restrictions upon his access to modern technology only holds true for those aspects of genetics

that require microscopy, not for the understanding of heredity that Mendel described.

While the breadth of scientific development that separated Aristotle from Watson and colleagues cannot be bridged, it is relevant to reflect on *why* Aristotle did not undertake experiments similar to those run by Mendel. Certainly, Aristotle was clever enough to devise them, but he did not see the need to conduct them, as indicated by the fact that he did, in fact, undertake some experiments with plants.[17] He also undertook many dissections of animals, thus suggesting that he was not averse to this kind of scientific endeavour. So, we can hazard the supposition that, had he wanted to, he could have discovered what Mendel did over 2,000 years later. It may profitably be asked "Why not?

The modern Scientific Method consists of a number of steps.[18] Although the Ancient Greeks established steps 1 (Observation of phenomena) and 2 (Hypotheses generation), they did not always continue to the third step (Experimentation to test the hypothesis).[19] It has been suggested that this is because: "Experiment, to some extent, was seen as manual labour, and as such beneath the dignity of a 'gentleman' philosopher" (Gregory, 2001, p. 159). Contrary to this suggestion, there is clear evidence in the GA and elsewhere that Aristotle performed many dissections of animals, activities that were quite laborious. Perhaps a more relevant argument as to why Aristotle did not perform the kind of experiments with plants that Mendel used to such advantage is that, prior to the 17th century, it was not known that plants had sexes.[20] Although Aristotle dissected animals, he did not undertake animal breeding experiments to elucidate the details of heredity, probably because that kind of experimentation requires relatively pure-bred animals, which were not readily available during Aristotle's time. Had he attempted such experiments, they would have had only a small chance of success because of the difficulty in isolating pure-bred animals with specific characteristics.

Instead, the syllogistic model of the Scientific Method that Aristotle followed was considered to constitute 'science' during his time, emphasising logic over experimentation (Hintikka, 1972, p. 55). In fact, Aristotle himself describes a syllogistic form of science without experimentation (Ferejohn, 1991, p. 5). However, the assumptions and hypotheses inherent within syllogistic models of thinking can only be finally tested by experimentation, such as that undertaken by Mendel.

It is also important to recall that, as Lange (1983, p. 7) says, “Aristotle’s notion of science includes not only a collection of “the facts”, but also “the reasons why” the facts are as they are observed to be”. The second part of this understanding of science may have led Aristotle to conclusions that are not based upon data from experimentation. That is, his desire to explain why heredity worked in the way it did, may have diverted him away from finding out how heredity actually worked, and instead into models of how it *ought* to have worked, based upon his need to formulate an explanation of heredity that fitted with his *zeitgeist*. The effect of the north wind on sex of offspring is an example of this: easily refuted by observation/experimentation, but part of the thinking of his time and therefore accepted into the model he constructed to explain heredity.

However, regardless of whether Aristotle undertook experimentation, he does make some comments about reproduction and heredity that are congruent with modern understanding, and which have stood the test of time and scientific development. It is salutary to reflect that the most accurate of his statements are not only based upon his observations but also upon his logical deductions. For example, his notion that semen is a ‘seed-aggregate’ that dictates the form of the offspring is not only very close indeed to modern models of chromosomes and genes, but also necessary for a logical model of trait differences between offspring from the same parents.

Aristotle’s similar claims mentioned above, including: offspring are more likely to resemble their parents than their grandparents, earlier ancestors, or strangers; all animals generate after their own kind; parental semen holds the key to the characteristics of the offspring; the presence and timing of the female menstrual discharge will dictate whether fertilization will occur; there are dominant and recessive parental characteristics that may be transmitted to the offspring or may miss a generation, depending on their dominance in the relative gene pool; and one ejaculation of the male semen is sufficient for many fertilizations to occur. All of these are congruent with the modern understanding of reproduction and heredity and are based upon Aristotle’s logical explanations for the observations he made and which he reports in GA.

The conclusion that emerges from this consideration of Aristotle’s model of heredity is that, despite not having access to the microscopy that would have revealed sperm, ova, chromosomes, and genes, Aristotle formed a construct about “semen” that is remarkably congruent with modern accounts that rely upon current technology. Although the lack of

experimentation in Aristotle's scientific method may be judged as being unfortunate (from a modern perspective), his understanding of heredity is clearly akin to modern models based upon genetics in some important aspects.

Notes

1. Perhaps exemplified by Armand Leroi, Professor of Evolutionary Developmental Biology at Imperial College, London, author of the semi-popular text and BBC TV documentary on "The Lagoon" and who, prior to discovering Aristotle's Historia Animalium, noted that "Ancient history had never held much interest for me; I am a scientist".

2. "Aristotle's method may be described as substantially the same as that of modern scientific workers: it is inductive-deductive, as opposed on the one hand to earlier (and later) methods of pure deduction from a priori premises, and on the other hand to the Baconian method of almost exclusive induction" (Peck, 1949, p. vii).

3. Aristotle could not have known about chromosomes, alleles, DNA, RNA, the five 'bases' that comprise nucleic acids that form DNA and RNA, mitosis, or meiosis, simply because he could not see them.

4. In order to access sources of detailed information and also sources of broader-based information, reference was made to two modern textbooks on genetics, one on physiology, plus several key articles in the Encyclopaedia Britannica. The two genetics textbooks were: (Klug et al., 1949) and (Snustad and Simmons, 2000). The text on physiology was (Hall, 2016). The Encyclopaedia Britannica articles were: (Carson and Robinson, 2021), (Allen, 2021) and (Robinson, 2021).

5. Also stated succinctly in *Metaphysics* V, 1033b as "for man produces man".

6. The proximity of the parents means that their gametes are sufficiently similar to produce a viable organism (i.e., mitosis can occur) but are too different to produce viable gametes themselves.

7. Mathematical modelling of the Neanderthal-homo sapiens interbreeding suggests that it was most likely due to "the exchange of a single pair of individuals between the populations at each 77 generations" (Neves and Serva, 2012, p. e47076).

8. Although there is some initial confusion about whether semen comes only from the male, or both the male and female.

9. Nor, as argued by Mayhew, is there a consistent argument along these lines from Aristotle: "Menses is in a sense passive, but in no sense is it totally inactive or indeterminate matter. It possesses a specific nature with motions of its own, and it is, potentially, the animal and its parts" (Mayhew, 2004, p. 50).

10. The release of a second egg produces 'Dizygotic' twins, also called 'fraternal twins', whereas the splitting of an embryo produces 'Monozygotic' twins, also called 'identical

twins' (although they are actually not purely identical: S Silva et al., "Why are monozygotic twins different?," Journal of Perinatal Medicine 39, no. 2 (2011).

11. Grene (2000) gives an aggressive response to Kullman's hypothesis, arguing that "the parallel (between Aristotle's comments and modern genetics) still escapes me", but does not provide a detailed evaluation of Aristotle's model of heredity, preferring instead to attempt to demolish Kullman: M Grene, "Recent work on Aristotelian Biology," Perspectives on Science 8 (2000). Pp. 455-456.

12. In general, 'phenotype' refers to the way an animal looks to us, its appearance, physiology, and behaviour; 'genotype' refers to the genetic factors (i.e., chromosomes) that dictate this phenotype.

13. Aristotle's terms for 'movements' and 'semen' are 'κινήσεις' and 'δυνάμει', from the Loeb edition, Aristotle, "Generation of Animals," in Loeb Classical Library, ed. G Henderson (Cambridge, MA: Harvard University Press, 1942). IV, 767b 37-38.

14. Nowadays, epigenetics refers to "the study of changes in gene function that are mitotically and/or meiotically heritable and that do not entail a change in DNA sequence." C Dupont, DR Armant, and CA Brenner, "Epigenetics: Definition, Mechanisms and Clinical Perspective," Seminars in Reproductive Medicine. 27 (2009). p. 351.CH Waddington, Principles of embryology (London: Allen & Unwin, 1956). P. 10.

15. 'Evolution and Development'. D Stern, "Conrad H. Waddington's Contributions to Avian and Mammalian Development, 1930-1940.," International Journal of Developmental Biology 44 (2000). p. 21.

16. There is also an opinion that, rather than being a specialised scientist (e.g., biologist, geneticist), "Aristotle is not a modern scientist", nor even "the father of the specialised sciences", but is instead "the last global thinker of antiquity": P Laspia, From Biology to Linguistics: The Definition of Arthron in Aristotle's Poetics (Champaigne, Ill: Springer, 2018). Pp. 1-2.

17. "but often a plant does not possess one part, and another may be removed...and yet this also comes into being with the same form as in the parent plant." Aristotle, "Generation of Animals." I, 722a 11-15.

18. (i) Observation of some phenomenon, (ii) Hypothetical explanations of that phenomenon, (iii) Testing of those hypotheses, (iv) Development of a 'theory' that explains the information gained so far, and (v) Reporting of that outcome.

19. Some Greek philosophers did undertake a form of experimentation in repeated observations of their hypothesis (e.g., Thales' method for measuring heights from a distance, Aristotle's descriptions of animal functions, Archimedes' experimentation with models of his machines), but this was not the norm, perhaps for reasons of social status or belief about what were appropriate activities for philosophers.

20. "Discovery of Sexuality in Plants," Nature 131, no. 3307 (1933/03/01 1933).

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KEY ELEMENTS OF REGULATORY ECOLOGY

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Abstract

Regulatory ecology is an evolving part of regulatory science. This paper attempts to address the unique structure of regulatory ecology. It identifies three groups consisting of eco-fundamentalism, eco-egoism, and eco-stewardship also known as eco-shepherding. The study suggests that the regulatory ecologist should follow the eco-stewardship process. The study identifies zoonosis as a part of regulatory ecology and implies that global human health would benefit from participation by ecologists in zoonosis activities. The study recommends substantial expansion of research funding for ecological research with the objective to enhance the reproducibility of ecological studies, notably regulatory ecology.

Introduction

THE HISTORY OF ECOLOGY BEGAN WHEN Ernst von Haeckel, a German zoologist, coined the term *ecology* (Őkologie in German) in 1866. Currently, ecology is a well-established scientific discipline, that seeks to study the relationships between plant and animal organisms and their environment and habitat (Sampson 1952, Oosting 1956, and Stiling, 1992). Understanding and applying ecological principles is complex and requires the study and application of many scientific disciplines. Currently many colleges and universities offer degrees in plant and animal ecology ranging from two-year associate degrees to doctorate levels. Also, many textbooks and scientific documents cover various areas of ecology. Helms (1998) describes what constitutes an ecosystem, its definition and evolution, how an ecosystem evolves and adapts over time in response to disturbance events and management activities, and numerous other issues related to ecology.

Given the desire of the global communities to protect ecosystems and selected species, numerous countries have established laws, policies, and regulations designed to reduce losses and associated negative effects of various activities and practices. One of the first laws dealing with

wildlife protection was the *Sea birds Protection Act* of 1869 that was enacted in Britain (Potter et al., 1973). In the United States there are many laws, policies, and regulations with the goal to protect the environment, plants, and animals that comprise ecosystems. Examples include the Forest Reserve Act of 1891; the Act of 1905 that created the U.S. Forest Service; and the Endangered Species Act (ESA) of 1973. A key statement within ESA requires that the decisions of the Secretary of Interior must be "based on the best scientific and commercial data available." Exactly how the best available scientific and commercial data are found is subject to considerable dispute. Consequently, there have been many disputes between and among regulatory agencies, such as the U.S. Department of the Interior, the U.S. Environmental Protection Agency (EPA), and environmental organizations, as well as the regulated community. Given the expected uncertainty, there have been many publications addressing the subject including the National Research Council (NRC 1995, 2004). Much like most other disciplines included in regulatory science, the regulatory ecology inherently includes various levels of uncertainties.

The earth's ecosystem is estimated to contain about one trillion microbial agents (Locey and Lennon 2016) including about five million species (National Geographic, 2021). The latter includes zoonoses caused by organisms that "jump" from an animal to humans. Typically, the pathogens may be bacterial, fungal, viral, or parasitic. As described by Kruse et al. (2004) many diseases have been caused by bioconversion of microorganisms to those that infect humans with consequences ranging from mild to chronic or severe. History includes many examples of zoonosis including the bubonic plague described in the Old Testament, the Black Death that occurred in 14th century in Asia, rabies, anthrax, avian influenza, Ebola, and many other diseases that continue to negatively impact many parts of the world. The corona virus known as COVID-19, if not altered by the Wuhan Institute of Virology, would be the most current example. This disease eventually spread globally with enormous human health consequences. The key question that relates to regulatory ecology is: Does ecological science play a role in managing zoonoses?

Ecosystems provide products that are necessary for their maintenance. For example, carbon dioxide is emitted by arachnids and microbes that decompose organic matter within the ecosystem while plants

process the carbon dioxide produced for growth and survival through photosynthesis that yields oxygen, water, and cellulose.

Humans have been dependent on plant and animal communities for meeting innumerable needs: including food, clothing, medicines, some forms of energy, shelter, and even cultural and recreational activities. This dependence is reflected from earliest recorded human history with Paleolithic cave art of animals. Throughout history, humans have enjoyed interaction with wildlife when not threatened. Even in cities and urban settings observation of wildlife is often considered to be enjoyable. The example of birds can be used to help demonstrate the point. There is ample evidence that humanity has enjoyed the voices of wild birds. How else can one explain that Ludwig van Beethoven in his pastoral symphony, composed over several years, used various musical instruments to mimic and synthesize sounds of nightingales, quail, and cuckoo in his composition of 1808?

Over the past century, but particularly during the past several decades, there have been extensive discussions on the role of humanity within the environment, the value of advocacy, and numerous other related subjects in various aspects of ecology. During this study certain relevant laws and several national and international reports were evaluated to identify key elements of the subject resulting in the following questions:

- What is an ecosystem and do humans have the right to interfere in ecosystems?
- Is there an inherent conflict between protecting humans and protecting an ecosystem and do humans have a right to protect humanity to the detriment of an ecosystem?
- Are humans an integral part of the ecosystem and if so, how should they treat other species in that system?
- If humans are a part of ecosystems, wouldn't it be logical that the rules governing all other species would also apply to them?
- Is it acceptable to commingle political and ideological goals with the desire to protect ecosystems hoping that at least one of the goals can be reached?
- Does science have any role in the protection of the ecosystem?
- How should a potential conflict between science and the protection of the ecosystem be reconciled?

- What is the role of ecology as a scientific discipline in identifying microorganisms generated in the ecosystem and their potential positive and negative impact?
- Is addressing issues related to zoonosis a part of ecology and if so, is the subject currently adequately addressed?

Categorization of Humans and Ecosystem

An evaluation of relevant literature identified three distinct categories or schools of thought regarding the role of humans in the ecosystem. In the following these groups are identified with different schools of thoughts or theories that describe how ecosystems should be managed and regulated.

Eco-Fundamentalism

Proponents of this school include traditional ecological scholars, scholarly organizations and advocacy organizations who implicitly include humans as an integral part of ecosystems and thus imply that rules that are applicable to other species also apply to them. This concept is frequently associated with the Romantic-Transcendental Preservation Ethic developed by Ralph Waldo Emerson, John Muir, and David Thoreau, which was nurtured more by empathetic experience, imagination, and romantic poetry, than by hard science (Callicott, 1991). The proponents of this school claim that ecosystems are based on the notion that the definition of ecology refers to all organisms, including humans. Similarly, this school implicitly or explicitly considers humans to be an integral part of ecosystem, and all species have equal rights and reasons for existence. Based on this philosophy the emphasis of environmental protection must be the protection of ecosystems, which include not only humans but many other species. Proponents of this school can be divided into two sub-groups as follows:

1. The first sub-group consists of the truly pure eco-fundamentalists. This group considers that humans have no more rights than other species. Consequently, humans can use natural resources to meet their basic needs, such as food but may only do so in a manner that does not interfere with overall ecosystem processes. The motto of this group is “nature knows best” and any interference with natural ecosystem processes would be unacceptable.

2. The second sub-group in this school accepts the notion that humans have the ethical obligation to ensure that all species are protected. However, it would prohibit the conscious killing of living species, except those that are immediately used for food or otherwise interfere in ecosystem processes. Accordingly, seeds may be planted for food and animals can be hunted, however, all living things have about the same right to reap the product of that effort. They support using natural means to increase productivity but oppose the application of other means such as pesticides for increasing production. Although this school would agree that trees may be cut down for specific purposes, deforestation is unacceptable.

Eco-Egoism

This school is based on the notion that protection of the ecosystem does not need to be considered in decisions that address human needs. It is sometimes referred to as Utilitarianism, a concept developed by Jeremy Bentham (Bentham, 1823), that focuses on a doctrine that promotes inexpensive food and fiber, industrial progress, and general prosperity that helps lead to human happiness. Although seldom openly advocated, the proponents of this school claim that protection or even consideration of ecosystem values inherently contradicts the interest of humanity. They point out that the definition of ecology is based on species or organisms and thus economic interest of humans, protection of human health, and numerous other interests of humans are in direct competition with other "organisms" including insects, fungi, and some that may be microscopic. According to this school, many organisms can be eliminated not only with no adverse impact on human life, but often with great advantage to human interests. How does one explain to an individual who is living next to the rainforest in Brazil that he cannot cut trees to raise food? How can one explain to this individual that the maintenance of the ecosystem is more important than feeding his children? This group has likely existed as long as humanity.

Eco-Stewardship

This school is also known as eco-shepherding: Proponents of this school claim that although humans live in the ecosystem, they are not equal members with other species, but possess the role and responsibility

of a steward to protect the environment and its ecosystems. This group has its roots in the Old Testament: Genesis and Deuteronomy, which teach that nature was placed by God in the hands of humans, to care for it as God's stewards (Floyd. 2002). As stewards of the environment, humans are to nurture and care for it. Gifford Pinchot developed the American Resource Conservation ethic that promoted wise use for the greatest good of the greatest number in the long run (Pinchot. 1947). Accordingly, based on the philosophical foundation of this group, humans have not only a moral, but also an economical reason to protect the ecosystem. Our actions must ensure the wellbeing and betterment of humans by producing food, fiber, and other natural resources, as well as avoiding and combating diseases. Therefore, humans must live within the ecosystem and must do so in a manner that seeks to responsibly conserve ecosystems. In the United States the earliest proponents of this school were Theodore Roosevelt and Gifford Pinchot.

Regulatory Ecology Groups

There are three regulatory science groups: The first group consists of ecologists working for regulatory agencies who write and enforce relevant regulations. The second group consists of ecologists who work for organizations and who must comply with relevant regulations. The third group performs research and development and provides the necessary information on regulatory ecology. It is desirable that this latter group in cooperation with the other two groups develops the structure of regulatory ecology and makes the information publicly available. Regulatory ecology should also attempt to predict and ideally avoid adverse events, such as damage to specific species and zoonosis.

Microbiology is a scientific discipline that deals with microorganisms including viruses and bacteria produced during the ecological process. There is also a well-known process consisting of infectious diseases caused by a pathogen that jumps from a member of a wildlife to humans called zoonosis. Due to the enormous impact of infectious diseases including those transmitted from wildlife, there are numerous publications addressing this subject. Regulatory ecology could play an important role in limiting the ecosystem-produced microorganisms. An appropriately managed regulatory ecology is likely to

identify causes of zoonosis, reduce the probability of adverse human microbial impact, and potentially avoid their generation.

Assessment Process

One of the key processes used in regulatory science consists of Best Available Regulatory Science (BARS) and Metrics for Evaluation of Regulatory Science Claims (MERSC) derived from BARS (Moghissi et al., 2017). Figure 1. Shows BARS/MRESC as described in several previous publications (Moghissi et al., 2015, 2018, 2019). The five principles of BARS consist of Open-mindedness, Skepticism, scientific rule, ethical rule, and Reproducibility. The Ethical Rule Principle is particularly applicable to regulatory ecology. Regulatory science transparency is a key element of regulatory science ethics and requires that scientific information assessments or any other scientific foundation of decisions be provided to the affected community and ideally the public. Accordingly, the regulators must provide the affected community with how scientific uncertainties were addressed.

Another key element of the Ethical Rules Principle is Communication, as expressed by the Jeffersonian Principle. William Ruckelshaus, the first Director of the EPA popularized a quotation by Thomas Jefferson leading to the Jeffersonian Principle, the foundation of regulatory science communication. Jefferson stated: “If we think [the people] not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it away them but to inform their discretion.” The Jeffersonian Principle categorizes the recipients of regulatory science information in three groups:

1. Scientific Specialists: Individuals with key scientific knowledge and experience in the scientific area that is being considered.
2. Knowledgeable Non-Specialists: Individuals that may be referred to as informed individuals.
3. General Public

As shown in Figure 1, the level of maturity of regulatory science starts with proven science consisting of scientific laws, also known as principles and their reproducible applications. As described above the implementation of ESA is associated with uncertainties. Consequently, much of regulatory ecology falls into evolving science and borderline science. Similarly, the reliability of regulatory science starts with peer-

reviewed science and reaches its highest level of reliability at consensus processed. A key and often violated pillar is “Outside the Purview of Science” and implies that societal objectives including ideology, may not be included in science. Often societal goals are included in scientific assessments. What is being overlooked in this concept is that being protective is a part of policy and not science.

Many regulatory ecology assessments inherently contain uncertainties. Much like any other regulatory science assessment, a properly performed regulatory ecology assessment must identify and describe the details of uncertainties and include the following:

- Any assumption or judgement
- Details of inclusion of default data
- Inclusion of societal objectives, ideology, or any other non-scientific issue
- Any other information that cannot be reproduced by an individual with relevant knowledge and access to necessary equipment and facilities.
- Justification for choices among various alternatives and the impact of consequences of key alternatives in regulatory decision processes.

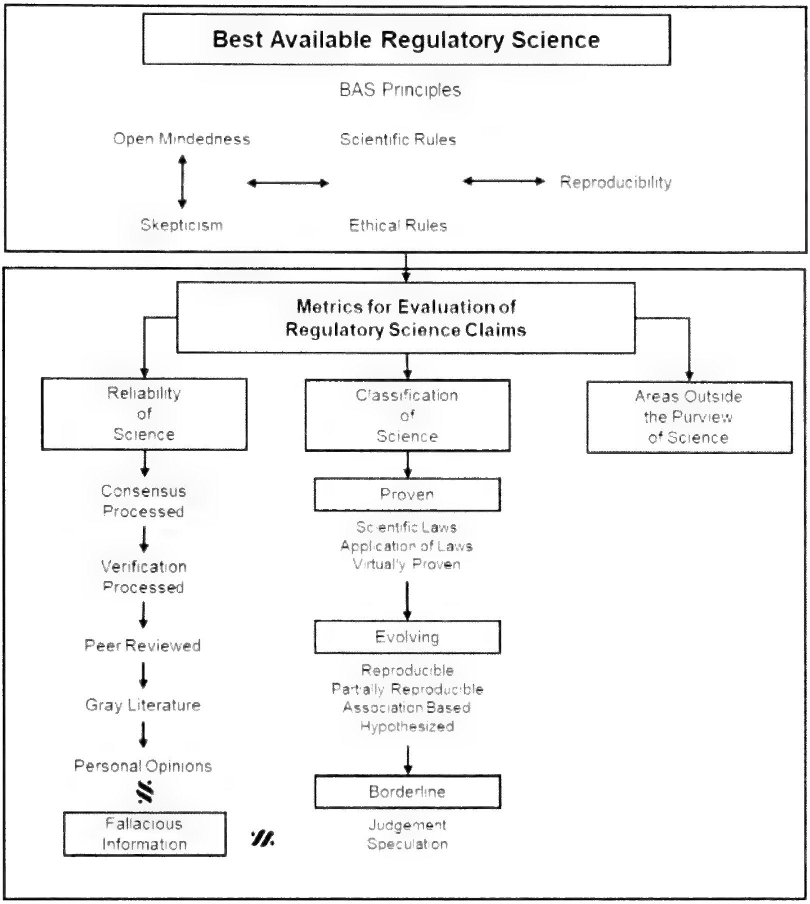

Figure 1. Best Available Regulatory Science and Metrics for Evaluation of Regulatory Science Claims

An example from the ESA can be used to demonstrate the point. Due to the anticipated uncertainties concerning species abundance, and distribution, the precautionary principle was used to help guide regulators with decision makings frequently erring on the side of species protection and designating species as threatened or endangered, despite the empirical evidence indicating that they were neither (Gordon et al., 1997).

Application of BARS/MERSC for Assessment of the Structure of Regulatory Ecology

The evolution of regulatory science (Moghissi et al., 2014) and its application to ecology requires a revaluation of the existing processes. In

addition, certain disciplines such as regulatory toxicology are reasonably well established, and their structure can be evaluated with the objective of applying their structure and experience to regulatory ecology. The following key elements of regulatory ecology are addressed and revaluated:

The development of regulatory ecology is likely to have a significantly positive impact not only in promoting ecosystem health, but also human health. The application of BARS/MERSC will identify the level of maturity and reliability of specific ecological information. Similarly, the identification of societal objectives, including ideology in regulatory ecology, will be most desirable. The inclusion of microbiological processes, notably zoonosis in regulatory ecology, will have a positive impact on human health and the economy.

There is ample evidence that the level of maturity of regulatory ecology, as used in the decision process, is often near the bottom of the pillar on the Classification of Regulatory Science. In addition, there is ample evidence that the level of maturity of regulatory ecology, as used in decision-making processes is often at the bottom of evolving regulatory science (as shown in Figure 1), and this component regulatory ecology is often at the level of Borderline Regulatory Science. In addition, when there is a lack in reproducibility of data, then an assessment may often include societal objectives. For these reasons, society would greatly benefit if the level of reproducibility of regulatory ecology information used in the decision-making process would improve.

The application of eco-stewardship would significantly improve the health of the ecosystem. It may be recalled that there were also two additional groups consisting of Eco-fundamentalism and Eco-egoism. It is necessary to address certain key issues of each group: The two groups covered under eco-egoism differ widely in their needs and logic. The remedy for those who damage the ecosystem because their livelihood depends upon it, such as to fight poverty and provide for the opportunity to support their family without damaging the ecosystem. In contrast, the second group in this school overlooks the fact that, although in the short term, they may have economic benefit, however the interest of society is not served by their actions. A correctly managed system optimizes the relationship between the operation and the needs of the entire society.

As the views of the first group of eco-fundamentalists are not shared by most of the proponents of that school, it is not further considered in this paper. Instead in the following discussion eco-fundamentalism refers to the second group.

If one accepts the notion that laws represent the views of the population, the passage of numerous laws dealing with air, water, food, and numerous other human health areas suggests the acceptance of the eco-stewardship philosophy by the electorate. There is an extensive agricultural industry that raises animals for food and the treatment of these animals that must follow certain ethical requirements. Similarly, the biomedical community uses animals for research in several scientific areas but must comply with ethical requirements of animal management. These requirements do not necessarily apply to eco-fundamentalism. Whereas eco-stewardship considers protection of human life and welfare to be the focus of environmental protection. Eco-fundamentalism considers the human species to be one of millions of species inhabiting the planet earth. Both philosophies value life; however, their ethical and societal consequences are profoundly different.

There is a difference between the philosophical foundation of eco-fundamentalism and eco-stewardship. Both schools agree that a wholesale destruction of an ecosystem or indiscriminate killing of species for short term economic gains is not desirable. Eco-stewardship implies that humans have the right to eliminate disease-carrying vectors and that humans have also the right to use agricultural products and wisely use natural resources.

Another potential difference between the two schools is the treatment of invasive species. These species move from one area to other areas, not only by planned or inadvertent human activities, but also by natural means. For example, seeds can be transferred long distances by winds, ocean activities, and numerous other processes. Although the proponents of eco-stewardship consider remedial action to be the responsibility of humanity, the philosophy of eco-fundamentalism has difficulty justifying any action.

A key difference between these two schools is whether society should protect the health of humans. There is a well-accepted principle that individual members of species that are at risk must be protected. The

same level of protection does not generally apply to all wildlife. According to the eco-fundamentalism school, humans are one of many species within the ecosystem. There is a group of investigators and others who claim that some species are overpopulated, and population control is desirable and necessary. Accordingly, the eco-fundamentalism school would have difficulties justifying the use of medicine or taking other measures to manage overpopulated species within the ecosystem. Such a problem does not exist for the eco-stewardship school.

Discussion

The adaptation of eco-stewardship also known as eco-shepherding in regulatory ecology would have significant scientific and societal implications for the relationship between humanity and the ecosystem. In effect, the ecosystem and humanity would support each other and provide unique opportunities in reevaluating many aspects of their interaction. Furthermore, the role of an ecosystem manager would be clearly identified as manager of the ecosystem. Also, it is highly desirable to initiate a study to evaluate the beneficial consequences of the application of eco-stewardship in regulatory ecology.

There is ample evidence that the level of maturity of regulatory ecology used in the decision-making process is a component of Evolving Regulatory Science and is often at the level of Borderline Regulatory Science. Society would greatly benefit if the reproducibility of regulatory science used in the decision-making process improved. The global community would greatly benefit from the close cooperation between regulatory ecologists and regulatory microbiologists in performing research and development. The primary objective would be to identify microorganisms with potential adverse human health effects, attempt to control the adverse effects, and undertake appropriate actions to reduce or eliminate their impact.

Conclusions

The advancement of regulatory ecology, including the application of eco-stewardship, would require substantial expansion of funds for research and development. The U.S. Congress is urged to expand research and development funds for regulatory ecology including zoonoses excluding funding for Gain of Function (GOF) research that is anticipated

to enhance the transmissibility and/or virulence of pathogens. NIH describes GOF as a "...type of research that modifies a biological agent so that it confers new or enhanced activity to that agent" (NIH undated). The relevant agencies such as the U.S. Department of Interior, the National Science Foundation, the U.S. Department of Agriculture, the U.S. Environmental Protection Agency, and several others that support ecological research should emphasize reproducibility of regulatory ecology including zoonoses. Taking such an action would not only save human lives but also reduce global spending in fighting diseases.

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FREQUENCY DISPLACEMENT LAW

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Abstract

In this paper we use Planck's Blackbody Radiation Law, which governs the intensity of radiation emitted per unit surface area at a fixed temperature. From this same law we can derive two other radiation laws: the Wien Displacement Law, and the Stefan - Boltzmann Law. The Wien Law gives the peak wavelength of the radiation distribution, while the Stefan - Boltzmann Law gives the total energy being emitted at all wavelengths by the blackbody or the area under the Planck's Blackbody Radiation Law curve.

Wien's law defines the horizontal slope of Planck's Blackbody Radiation Law as a function of wavelength and temperature. We provide the steps for deriving Wien's Law mathematically. We also derive the horizontal slope of Planck's Blackbody Radiation Law as a function of frequency and temperature.

It is understood that in purely electromagnetic phenomena there is a linearity between frequency and wavelength, they are inversely proportional. Whereas; blackbody peak frequency and wavelength are functions of an additional parameter that is temperature. Their product remains to be evaluated.

Introduction

A BLACKBODY IS AN EXTREMELY OPTICALLY thick medium where radiation (even though being part of the electromagnetic spectrum) becomes trapped for a long time. A blackbody eventually comes into equilibrium with its surroundings. Its distribution of energy in terms of both wavelength and frequency follows Planck’s function (Joos, 1986; Kakovitch, 2012; Weidner, 1960). When the slopes of Planck’s function in terms of wavelength or frequency are zero, then associated peaks occur. These peaks are not solely functions of wavelength and frequency *but also temperature* (different temperatures in stars produce different peaks).

Wien’s Displacement Law (Menzel, 1960; Schroeder, 1999; Weidner & Sells, 1960) tells us that Plank’s Blackbody Radiation Law gives a distribution that peaks at a specific wavelength for specific temperatures but mentions nothing about a distribution that peaks at a

specific frequency for the same temperature. Perhaps it was assumed that an inverse relation existed between frequency and wavelength that would always equate to the invariant speed of light. The product of peak wavelength by peak frequency should describe a portion of the pure electromagnetic velocity, but it is also influenced by the energy distribution related to scalar temperatures.

Method

Mathematically, the properties of electromagnetic radiation interacting with matter follow the rules of blackbody radiation.

The power emitted from the surface per unit solid angle as a function of wavelength λ for fixed temperature θ is given by the Planck's Blackbody Radiation function as shown by Equation (1):

$$B(\lambda,\theta)=\frac{2hc^2}{(e^u-1)\lambda^5} \quad (1)$$

where $u=\frac{hc}{k\theta\lambda}$, and where *h, c,* and *k* are defined in the Glossary below.

The partial derivative of $B(\lambda,\theta)$ with respect to λ is given by Equation (2):

$$\frac{\partial B(\lambda,\theta)}{\partial\lambda}=2hc^2\left(\frac{ue^u}{(e^u-1)^2\lambda^6}-\frac{5}{(e^u-1)\lambda^6}\right)=2hc^2\frac{(u-5)e^u+5}{(e^u-1)^2\lambda^6} \quad (2)$$

To maximize $B(\lambda,\theta)$ set the partial derivative $\frac{\partial B(\lambda,\theta)}{\partial\lambda}$ to 0. Since λ, *h, c,* and *k* are all positive, the partial derivative is 0 when Equation (3) holds:

$$(u-5)e^u+5=0 \quad (3)$$

Setting $w = u-5$ and solving for $w\,e^w$, Equation (3) becomes Equation (4):

$$we^w=-5e^{-5} \quad (4)$$

Therefore, $w = W_0(-5e^{-5})$, where W_0 is the principal branch of the Lambert W function. One can compute an approximate value for *w* with a hand calculator using Newton's method to find that $B(\lambda,\theta)$ is maximized when *w* is approximately equal to -0.0348857682557236963. Applying the

definitions of w and u, the wavelength λ_{peak} where $B(\lambda,\theta)$ is maximized is given by Equation (5):

$$\lambda_{peak}=\frac{hc}{k\theta\left(5+W_0\left(-5e^{-5}\right)\right)}\approx 0.20140523527264218062\frac{hc}{k\theta} \tag{5}$$

Equation (5) is Wien's displacement law.

The power emitted from the surface per unit solid angle as a function of frequency ν and temperature θ is given by Plank's Blackbody Radiation function shown in Equation (6):

$$A(\nu,\theta)=\frac{2h\nu^2}{\left(e^u-1\right)c^2} \tag{6}$$

where $u=\frac{h\nu}{k\theta}$ and where h, c, and k are defined in the Glossary below. The partial derivative of $A(\nu,\theta)$ with respect to ν is given by Equation (7):

$$\frac{\partial A(\nu,\theta)}{\partial \nu}=\frac{2h}{c^2}\left(\frac{-\nu^2 u e^u}{\left(e^u-1\right)^2}+\frac{3\nu^2}{e^u-1}\right)=\frac{-2h\nu^2}{c^2}\left(\frac{u e^u-3e^u+3}{\left(e^u-1\right)^2}\right) \tag{7}$$

To maximize $A(\nu,\theta)$ set the partial derivative $\frac{\partial A(\nu,\theta)}{\partial \nu}$ to 0. Since ν, h, c, and k are all positive, the partial derivative is 0 when Equation (8) holds:

$$(u-3)e^u+3=0 \tag{8}$$

Setting $w = u-3$ and solving for $w\,e^w$ Equation (8) becomes Equation (9):

$$we^w=-3e^{-3} \tag{9}$$

Therefore, $w=W_0\left(-3e^{-3}\right)\approx -0.17856062787792110 66$ · Applying the definitions of w and u, the frequency ν_{peak} where $A(\nu,\theta)$ is maximized is given by Equation (10):

$$\nu_{peak} = \frac{k\theta\left(3 + W_0\left(-3e^{-3}\right)\right)}{h} \approx 2.821439372122078893 4\frac{k\theta}{h}$$

(10)

Multiply Equation (5) by Equation (10) to obtain the product of the peak frequency and wavelength in Equation (11):

$$\lambda_{peak}\nu_{peak} = \frac{3 + W\left(-3e^{-3}\right)}{5 + W\left(-5e^{-5}\right)} c \approx 0.568252660549743131 1\ c$$

(11)

Finding

To avoid confusion over making statistical assumptions, convolving distributions and allocating them to parts of the electromagnetic spectrum, this paper merely points out three aspects of Wien's displacement law that we have presented:

1. There may be a primary modality that may have been ignored in blackbody radiation, that the radiation released is at both the blackbody's peaks for wavelength and frequency.
2. Temperature is significant for both peak wavelength and peak frequency, as per Equations (5) and (10). The blackbody peak frequency also changes in stars with different temperatures.
3. However, the product of the two peaks is temperature independent as per Equation (11).

Conclusion

In electromagnetic fields the product of frequency by wavelength equates to the speed of light. Whereas, with respect to the product of blackbody peak frequency by blackbody peak wavelength, such equality no longer exists, and the product equates to a specific fraction of the speed of light. This product does not produce particles as photons, which must travel at the speed of light, but rather indicates that a significant number of particles may be produced which travel at a fraction of the speed of light as seen by equation (11).

Glossary

c = 299792458 m/s is the speed of light in a vacuum (exact).
e = 2.71828182845904523536... is Euler's number.
h = 6.62607015×10^{-34} $J\cdot Hz^{-1}$ is Planck's constant (exact).
k = 1.380649×10^{-23} $J\cdot K^{-1}$ is the Boltzmann constant (exact).

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